Relating the Optical and Acoustical Properties of Oceanic Particles

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LONG-TERM GOALS

- To develop improved predictive capabilities for the distribution of particulate material in the coastal ocean.

- To develop predictive models for optical properties from measurements of acoustical properties and vice versa.

OBJECTIVES

To understand the relationship between acoustical and optical properties of suspended particles as a function of the particle's composition, size distribution and degree of aggregation.

APPROACH

Laboratory experiments of aggregation have been taking place at the University of Maine MISC Lab. The experiments are designed to measure the optical and acoustic response to inorganic aggregates, namely induced clusters of flocculated clays. The experiments are conducted in a large sink to allow for simultaneous measurements by several instrument all focused on the same depth.

Measurements include near forward optical scattering (providing information of cross-sectional area, and thus size, of aggregates, LISST, Sequoia Scientific), optical transmission and backscattering (WET Labs' BB(RT)) and acoustical backscattering at 4.5MHz (Nortek's VECTOR). Concentrations of clays are siphoned out from the sampling volumes of the sensors and measured using suspended sediment (TSS) analysis protocols.

These data are used to contrast the optical and acoustical responses to temporal changes in particle's concentration and size as a result of settling and aggregation. Collected material for mass and analysis of the time dependent signal allow us to study the change in acoustical and optical backscattering per mass as function of aggregate size. Experiments including organic glues and stirrers will allow us to

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vary the fractal dimension of aggregates (a measure of how compact an aggregate is) and its effect on the mass normalized acoustical and optical response.

Field data from the OASIS deployments which includes an extensive data set of optical and acoustical properties are investigated to find relationships between acoustical and optical properties as well as link them to processes identified in the water.

WORK COMPLETED

We have conducted two laboratory aggregation experiments including acoustic backscattering, optical backscattering, attenuation and near forward scattering.

We have four sets of measurements have been obtained, the first during August-September 2004, the second during August-September 2005, and the third during August-September 2007. A forth experiment has begun and will continue until mid-November 2009. All four sets of measurements have occurred at the Martha's Vineyard Coastal Observatory (MVCO), which is operated by the Woods Hole Oceanographic Institution (WHOI). Acoustical data collected during these experiments have been processed and readied for an extensive analysis.

RESULTS

Laboratory experiments were performed in the summer of 2009 to assess the effects that aggregation may have on the backscatter response of an Acoustic Doppler Velocimeter (ADV). A LISST-B was also used in the experiment, placed side by side with the ADV to track changes in average particle size over time. The acoustic intensity, measures of suspended particle mass (TSS), and the acoustic intensity normalized by mass (Figure 1, from top to bottom), demonstrate that the signal begins to decrease through the latter half of the experiment where smaller particles flocculate together to form larger aggregates that settle out of the sampling volume. The signal intensity follows the concentration (Figure 2), which is consistent with acoustic scattering theory. This consistency implies the insensitivity of the acoustical/mass ratio to aggregate size. It appears that the compaction of the aggregate is loose enough such that the acoustic fields generated by different scattering centers do not seemingly interact, a characteristic of the acoustics that is not observed optically. Optical data from the same experiments indicate that optical properties are also close to constant throughout the growth of the aggregates. Together this suggests that whatever relationship acoustics and optics have it will not be modified through aggregation.

IMPACT/APPLICATIONS

Acoustical properties have been used to predict particulate mass in coastal area. Our laboratory data suggest that at high frequency acoustical data is not sensitive to aggregation of the material preserving the linear relationship between acoustic scattering and mass. Consistency of optical and acoustical properties through aggregation suggest that this process will not modify their relationship and hence the ability to predict one from the other.

RELATED PROJECTS

This project is closely linked to the OASIS project (N000140410235 to E. Boss) which provides field data.

PUBLICATIONS

Russo, C. and E. Boss, 2009. Calibration of Acoustic Doppler Velocimeters to obtain the concentration of suspended mass in water. Submitted to J. Acoust. Soc. Am. [unpublished, refereed]

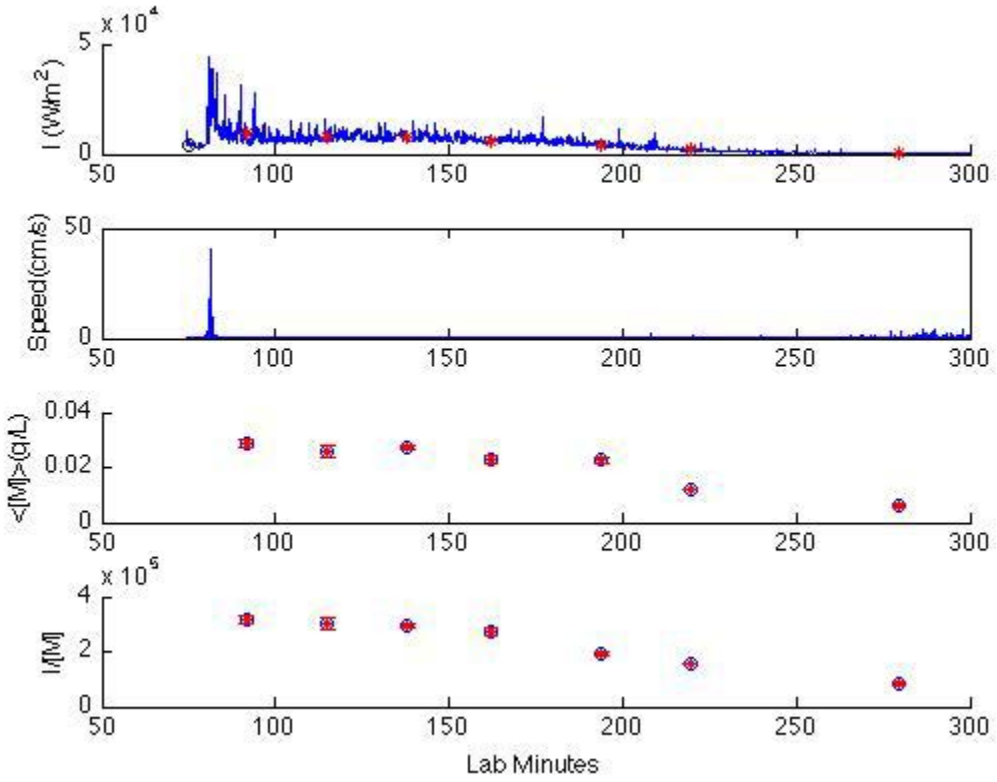

Figure 1. Time series of (top to bottom) acoustic intensity, speed, mass concentration samples, and mass normalized acoustic intensity. The (o) and (+) in the acoustic intensity series indicate the time that salt was introduced for aggregation and each moment of mass sampling, respectively. Error bars are displayed for the standard error in the mass sampled and for the mass normalized intensity.

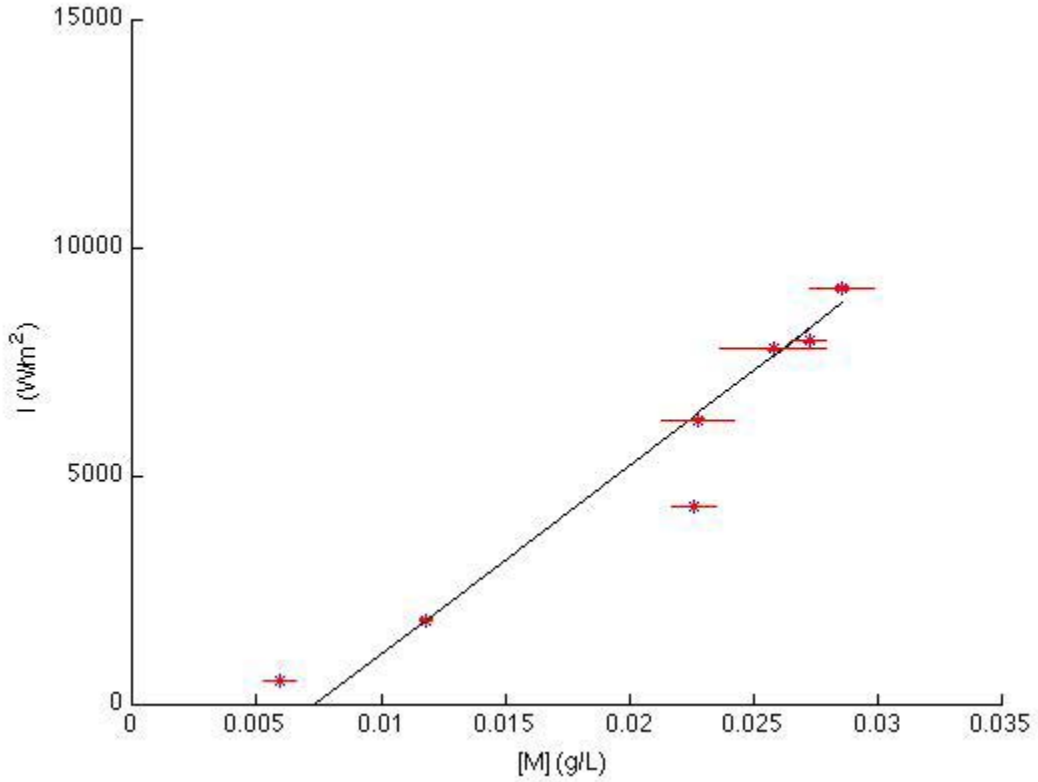

Figure 2. Acoustic intensity as a function of mass concentration, as sampled throughout the experiment. The data is fit to a line according to the theory for acoustic scattering and error bars account for uncertainties in both directions.